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Comparing Avian Diversity and Anthropogenic Disturbance at Sendero Los Quetzales Cerro Punta, Panamá

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Spring 2015

I. Abstract

This report summarizes the survey of land and avian diversity along a transect that runs from the exterior to the interior of the Los Quetzales Trail of Parque Nacional Volcán Barú in Cerro Punta, Chiriquí, Panamá. The region of Cerro Punta is Panamá's primary producer of produce and also home to one of the most biodiverse land reserves in the world. Despite protection efforts the area is continuously threatened by human development. The study juxtaposes calculated Shannon-Wiener Biodiversity Indices across graduated levels of anthropogenic disturbance to determine if there is a significant difference in biodiversity between areas with low, intermediate, and high disturbance. Surveys were conducted using a Timed Species Count (TSC) and rapid vegetation assessments. Analysis revealed that although there is not significant difference in biodiversity between areas with low and intermediate disturbance, there is a significant different between the biodiversity of both low and intermediate disturbed areas and the biodiversity of highly disturbed areas. Due to its small scale, these conclusions are limited to the area of investigation. However, this information may be helpful to conservationists hoping to preserve the diversity in Cerro Punta and along the Los Quetzales Trail.

III. Acknowledgements

I would like to thank Aly Dagang and Julio Tenorio for providing unconditional support to our entire study abroad group throughout this semester. I would also like to thank Señora Belgica de Durfey for opening her home and kitchen to me for the duration of my time in Panamá city. I would also like to thank Chelina Batista for opening my eyes to the wonderful world of birding and assisting me throughout my research, and Zeke Jakub, who helped who helped me collect equipment and understand the birds of the Western Highlands. I would also like to thank Genover "Ito" Santamaria for guiding me through Sendero Los Quetzales, driving me up the mountainside every morning, and showing me species that some people spend their entire lives hoping to see, and Ana Sanchez and AMIPILA for providing a comfortable, enjoyable place to stay in Guadalupe, Chiriquí. In addition, I would like to thank Yasmin for a wonderful Spanish class. Last, I would like to thank my family and friends for always being the best and keeping it real.

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IV. INTRODUCTION

The Earth's various natural environments are our lifeblood. Each terrestrial and aquatic biome is interconnected to provide the resources and habitats required to sustain the billions of organisms that thrive throughout this planet. The interconnectivity extends so deeply that the destruction of just one element, such as avian diversity, can have severe implications on the world's entire ecosystem. Around the globe, avian species are responsible for seed dispersal, insect management, and also serve as food for larger predators. Each species performs a role and occupies a niche that is essential for the maintenance of our fragile forests. In return, the forests regulate global climate, sequester carbon, and provide a habitat for the thousands of organisms living below and above the canopies.

Unfortunately, these habitats are at risk due to the Earth's growing human population and increasing demand for resources. This has lead to the rapid destruction of natural environments on land and in water. Global deforestation is occurring faster than we are able to inventory. This is particularly evident in the neotropics of Panamá, where forests are shrinking due to anthropogenic disturbances. To prevent complete destruction of some of the world's largest and most valuable forests, UNESCO, along with the Panamanian and Costa Rican governments, have created a series of land reserves to prevent the total loss of species and habitats.

Despite conservation efforts, anthropogenic disturbances continue to threaten forests and populations. Just as we depend on trees to filter CO_2 gas, we depend on farmers to provide food, and loggers to provide timber for construction. Therefore, it is important that we find a balance between the needs of Mother Nature and mankind. By studying the effects of anthropogenic disturbances we can better understand the relationship between humans and nature, and ultimately devise management plans that protect both producers and forests.

Cerro Punta is a town in the Western Highlands of Panamá that borders both Parque Nacional Volcán Barú and Parque Internacional La Amistad. This region is one of the most biodiverse land reserves in the world, and it is also home to the country's primary agricultural producers. Cerro Punta struggles to balance the preservation of its sensitive habitats and the demand for produce. Farmers continue to encroach upon the forest edges in search of fertile soils, while the Ministry of Environment struggles to implement and manage protection plans in the area.

The effects of this encroachment can be understood by comparing the species diversity in virgin forests to the species diversity of areas that have been disrupted. Biodiversity indices can be compared over time and space and can also serve as an assessment of forest health. In this investigation I survey avian diversity inside and outside the Los Quetzales Trail of Parque Nacional Volcán Barú. The sites investigated compare diversity between areas of low, intermediate, and high anthropogenic disturbance to determine if there is a significant difference between the diversities found in primary and anthropocentrically disturbed forests. Diversity indices are compared with an ANOVA and T-test. Species richness was used to calculate a Jaccard Coefficient and Simpson Index. The results allow for the interpretation of forest health and also shows which conditions are capable of maintaining avian diversity and which are not.

This report also provides information and suggestions regarding the development of the agricultural industry in Cerro Punta, Chiriquí.

V. LITERATURE REVIEW

1. UNESCO Biosphere and Parque Nacional Volcán Barú

Western Panamá is home to one of the most biodiverse land reserves in the world (Shapiro, 2001). Established in 1990**,** the La Amistad biosphere is a series of protected areas that span more than 650,000-hectares from Southern Costa Rica to Western Panamá. The two countries share the biosphere's largest park, Parque Internacional La Amistad (PILA). In Panamá, six auxiliary areas add to the reserve, occupying land in both the Chiriquí and Bocas del Toro provinces (Hofstede et al. 2013). Within the region lies the Cordillera de Talamanca Mountain range. The range's equatorial proximity and unique topography has shaped the land into six of the twelve Holdrige life zones (Jones, 2006), which support one of the most diverse, yet sensitive, ecosystems in Central America. Over 11,000 different species of flora and fauna have been recorded within the biosphere, including more than 22 "IUCN Red List" endangered species (WCMC, 1992). The biosphere is valued for its outstanding biodiversity, carbon-sequestering forests, and aesthetic beauty. Consequently, it is a focal point for conservation activity.

One of PILA's supporting reserves is Parque Nacional Volcán Barú. Located between the towns of Cerro Punta and Boquete, the park is esteemed for its emerald canopies, assorted wildlife, and historical significance. Pre-ceramic sites dating back more than 12,000 years have been discovered here, providing important information about early Central American civilization (WCMC, 1992). The park is home to the inactive Baru Volcano, whose summit is Panamá's highest point of elevation (3478m above sea level) (Reid, 2004). The climate ranges from anywhere from 10° to 20° Celsius with an annual rainfall between 2,000 to 6,000 mm (WCMC, 1992) Despite its relatively small size, the park contains areas of several different forest habitats including lower-montane rain forests, montane rain forest, lower-montane wet forests and premountainous rainforests (ANAM, 2015).

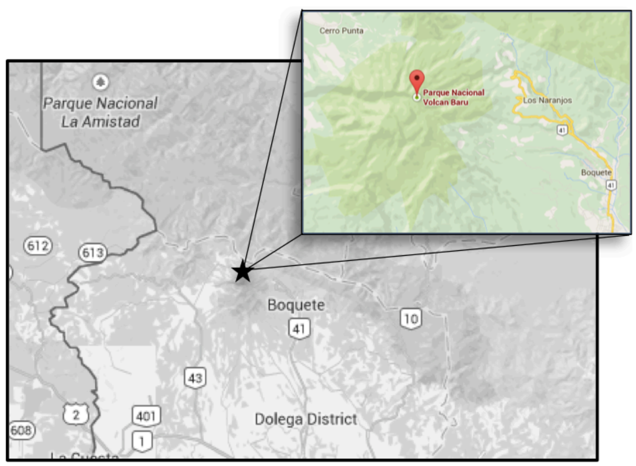


Figure 1: Location of Parque Nacional Volcán Barú. Google Maps (2015

The National Park's climate and lush, pristine forests provide the habitat for one of the most biodiverse avian populations in the Western Highlands (Angehr et al., 2006). More than 250 bird species have been observed in the park, including the heavily sought-after Resplendent Quetzal, the endemic Black-cheeked Warbler, and the endangered national bird of Panamá, the Harpy Eagle (Angehr et al., 2006). Despite management and conservation efforts, the park’s boundaries continue to be threatened by the anthropogenic encroachment of the surrounding areas (Hofstede et al. 2013).

2. Cerro Punta

Like the surrounding parks, the region of Cerro Punta is distinctive due to its unique intrinsic and extrinsic value. Located on the Pacific watershed of the Talamanca Mountains, the area is nestled in a valley found at the intersection of PILA and Parque Nacional Volcán Barú (Cohen and Dannhaeuser, 2002). Compared to other parts of the country, Cerro Punta is relatively cool, with an average yearly temperature of about 15°C. The area receives adequate sunshine and rainfall and, as a result of the Baru’s volcanic activity, the soil is notably fertile (Angher et al., 2006). The combination of these characteristics makes the region ideal for agriculture and crop cultivation. Consequently, Cerro Punta has evolved to be the most important agricultural region in Panamá, and is responsible for the production of 85 percent of the nation’s produce. To keep up with increasing demands, farmers have resorted to chemical treatment and mechanized production practices to optimize crop yields (Cohen and Dannhaeuser, 2002). Such practices have stripped existing plots of their fertility, forcing farmers to expand their operations inside of the protected boundaries. Furthermore, additional roads have been constructed to support the transportation of food from the region, and several dams have been constructed to meet the country’s growing energy needs. These advancements have resulted in localized deforestation and fragmentation of the surrounding woodlands (Hofstede et al. 2013).

Figure 2: Agrochemical store. Guadalupe, Chiriquí (2015)

Throughout Cerro Punta and the other small surrounding towns, it is easy to see the impacts of agriculture. Large clearings and monoculture farm plots reach far up the hillsides. The streets are lined with agrochemical supply stores or processing plants (Figure 2). Ironically, Cerro Punta is also home to over a dozen environmental NGOs under the umbrella name Alianza para el Desarrollo Ambiental de Tierras Altas, or ADATA. ADATA works to protect and preserve the ecosystems of the Chiriquí Highlands. Even though UNESCO, the Panamanian government, and the nongovernmental agencies have created cooperative, multidimensional management plans, the parks remain at risk due to increasing demands of the growing population. To satisfy the need for an appropriate balance between environmental protection and food security, more research is needed to understand the relationship between people, biological landscapes, and local species diversity. Only after we understand these relationships will we able to establish a management plan that fulfills the needs of both the population and environment.

3. Biogeography and Anthropogenic Disturbance

There is a complex relationship between physical landscapes and their resident biodiversity. Biogeography is the study of the relationship between species and landscapes over time. Species variation between regions can be influenced by the physical characteristics of the ecosystem — such as changes in latitude, elevation, isolation, and habitat. Historically, species variation has been a consequence of natural disturbances, such as volcanic eruptions or the rise of a new land bridge, like the isthmus of Panamá. Recent history has illustrated that human activity is threatening habitats. Species and ecosystems are experiencing more frequent and significant disturbances over shorter periods of time. Governments, industries, and corporations have defaulted to aggressive practices that create anthropogenic disturbances powerful enough to destroy entire populations and ecosystems. The case of the Panamá Canal is one example of this occurrence. Constructed in 1901, the Canal destroyed any habitat that stood in its way. When the Chagres River was dammed to form Lake Gatun, part of the forest flooded, creating a standing water matrix unsuitable for terrestrial or arboreal life. Not only did the construction completely destroy a portion of the forest, but it also created the island habitat, Isla Barro Colorado (BCI). Over the past 25 years, BCI has experienced 19 avian extinctions, and the area struggles to provide the necessary resources to maintain the diversity it once had as a mainland rainforest (Robinson, 2001). The Island Biogeography Theory explains this process, and it predicts that similar extinction rates and decreases in biodiversity will occur on land when an area becomes isolated by deforestation or fragmentation (MacArthur and Wilson, 1967).

Anthropogenic terrestrial habitat conversions can have sever implications. Typically, farmers, ranchers and loggers clear land for cultivation, livestock, or timber. This process results in open fields separated by or scattered with forest fragments. The process is often contagious; one clearing leads to another (Luarance, 2008). This contagiousness is evident in Cerro Punta. Clearing for industrial use redefines the forest edge, creates matrices unfit to maintain connectivity, alters species-community interactions, and dismantles ecosystem synergy. This leads to increased mortality, disease, competition, and population extinction, with a decrease in species richness (Luarance, 2008). These changes are detrimental to biodiversity and challenge conservation initiatives.

The effect of a disturbance on biodiversity is largely determined by the severity of disturbance and the type of biogeographic landscape that is created by the disturbance. (Martinez-Morales, 2004). Recently, we have observed that there are profitable alternatives to traditional large forest clearings. Agroforestry systems, specifically those growing café, cacao, and bananas, have shown to support species diversity, richness, and abundance (Harvey and Villalobos, 2007; Philpott et al., 2008). Plantation forests, such as forests cultivated for timber, rubber, or carbon fixation, are also known to provide a valuable habitat for a variety of species (Brockerhoff et al., 2008). At times intermediate disturbance to an ecosystem have also been shown to increase biodiversity (Mendoza et al., 2014). Studying the differential effect of disturbances to biodiversity across different landscapes may reveal whether certain scenarios are likely to have minimal or profound impact on biodiversity. Conversely, understanding these relationships may lead to the development of interventions designed to mitigate the effects of human activity and conserve habitats and wildlife.

4. Monitoring Forests through Avian Diversity

Parque Nacional Volcán Barú is home to more than 250 avian species. Each individual performs a variety of functions to help maintain forest health. Some species feed on insects and help manage insect populations while other species feed on seeds and help with dispersal for propagation. Forest health and avian diversity are interconnected. Deforestation reduces the space and resources necessary for a plethora of avian species to coexist and leads to a decrease in species richness. Studying the effects of anthropogenic disturbance on avian diversity not only helps understand the direct relationship between disturbance and birds, but also indirectly provides information about overall forest health. Changes in avian biodiversity within a specific location can serve as a barometer of the condition of an ecosystem (Chambers S.A., 2008). It is also common to use bird survey data to analyze habitat fragmentation and designate protected status. It is important to realize that there are many methods for surveying birds and careful consideration of the research objective must be taken when designing an assessment tool. When questioning the impact of human-induced habitat-variation it is best to use methods that index species diversity (Sutherland et al., 2004).

VI. RESEARCH QUESTION

Is there a difference in avian diversities between areas with low, intermediate, and high anthropogenic disturbance at the interior and exterior portions of the Los Quetzales Trail of Parque Nacional Volcán Barú, Cerro Punta, Chiriquí, Panamá?

VII. RESEARCH OBJECTIVES

1. Classify the level anthropogenic disturbance present outside, at the edge of, and inside Parque Nacional Volcán Barú along Sendero Los Quetzales.

2. Identify avian diversity at various levels of anthropogenic disturbance and compare the results using SWBI, Jaccard Coefficient, Simpson Index, and ANOVA analysis

VIII. METHODS AND MATERIALS

1. Overview

For five days I traveled to the Los Quetzales trail from the small town of Guadalupe, Chiriquí. I began my research with a transect that ran from the exterior of the trail to the interior of the trail. I established a total of seven observation plots: three exterior, three interior, and one at the trail's edge. Each morning and each afternoon I conducted two 60-minute "Timed Species Counts" (TSC), along with with 60-minute audio recordings. During the mid-day, I evaluated each site's geography and level of anthropogenic disturbance with a rapid vegetation assessment. Figure 3 shows an overview of the investigation.

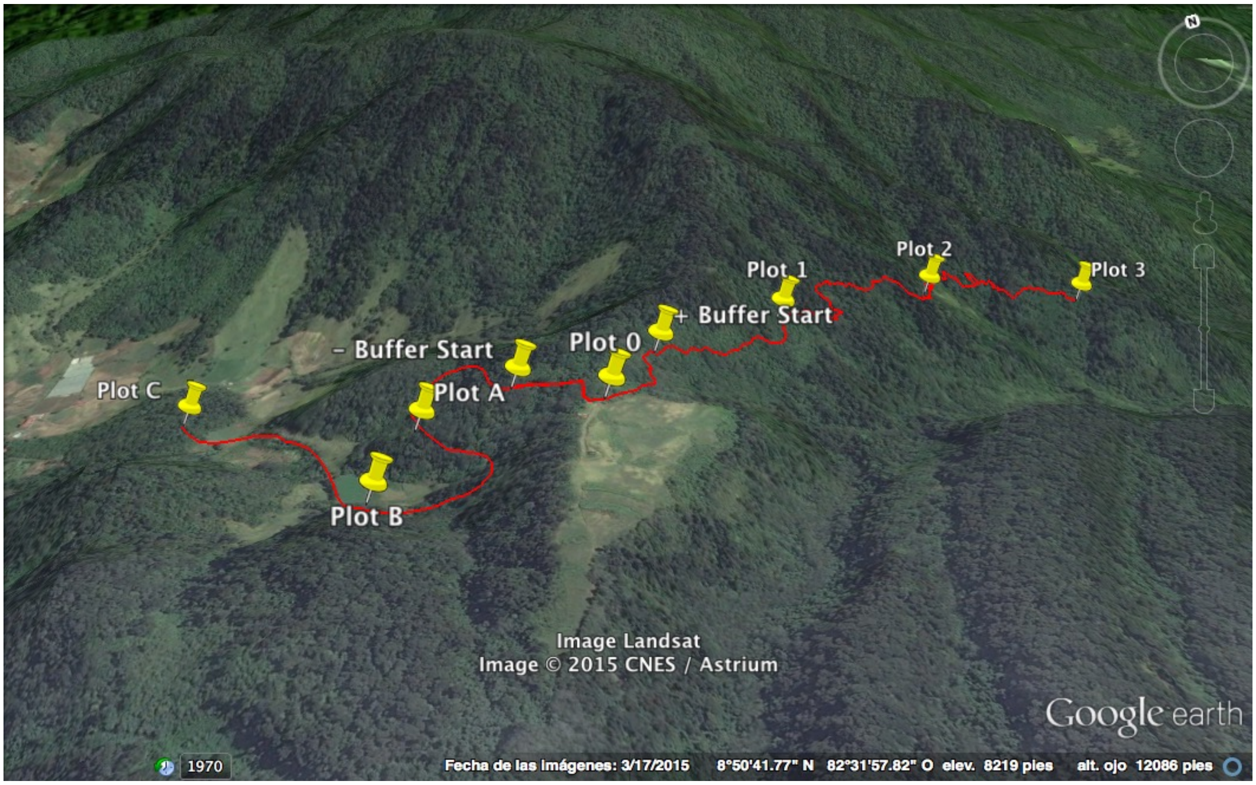


Figure 3: Overview of Project Site

2. Testing Audio Equipment

Before I began surveying, I tested the audio equipment's ability to capture volume and frequency in an open field. My audio setup included a Sony ECM-DS70P stereo microphone, a Sony ICD-PX440 stereo recorder, and my iPhone, pre-loaded high frequency and low frequency birdcalls. I extended a 30-meter measuring tape and placed the recording device at the origin of the radius. I then walked five meters, called out the distance on the tape measure, and played both the high and low frequency birdcalls. I continued this process every five meters until the end of the measuring tape. Using the Audacity software, I determined the range that the equipment was capable of recording a bird's song clearly.

3. Laying the Transect

Before arriving at the trail I utilized Google Earth software and a pre-routed GPS track to fix a central plot, Plot 0, at the trail's edge. I then established a 250-meter buffer zone on either side of Plot 0. I began to lay the additional plots at the edges of this buffer zone. Plots 1, 2, and 3 are located within the forest trail, while plots A, B, and C were located outside the forest trail. To determine the distance between each plot, I took the sum of a dice roll, and then converted it to meters. In the case of Plot 1, the sum of the dice was 5, so Plot 1 was placed 500 meters from the last plot (in this case, the end of the buffer zone). I continued to roll the dice for Plots 2 and 3. To determine the distance between A, B and C, I used the same method, but in the opposite direction of Plot 0, starting at the edge of the buffer zone. For each plot I rolled a single die to determine which side of the trail I would observe from. If the die was even, I would stand to the East of the trail, if it was odd, I would stand to the West. Last, I used the sum of a final dice roll to determine how many meters from the trail I would stand. This process of randomization is adapted from Alfered, 2012, and is summarized in Table 1. On Sunday, April 12th, 2015, I traveled to the Los Quetzales trail and marked each plot and buffer zone edge using the Garmin GPSMAP 64s and marking tape. The transect is diagrammed in Figure 4.

Table 1: Method for randomization of plot locations

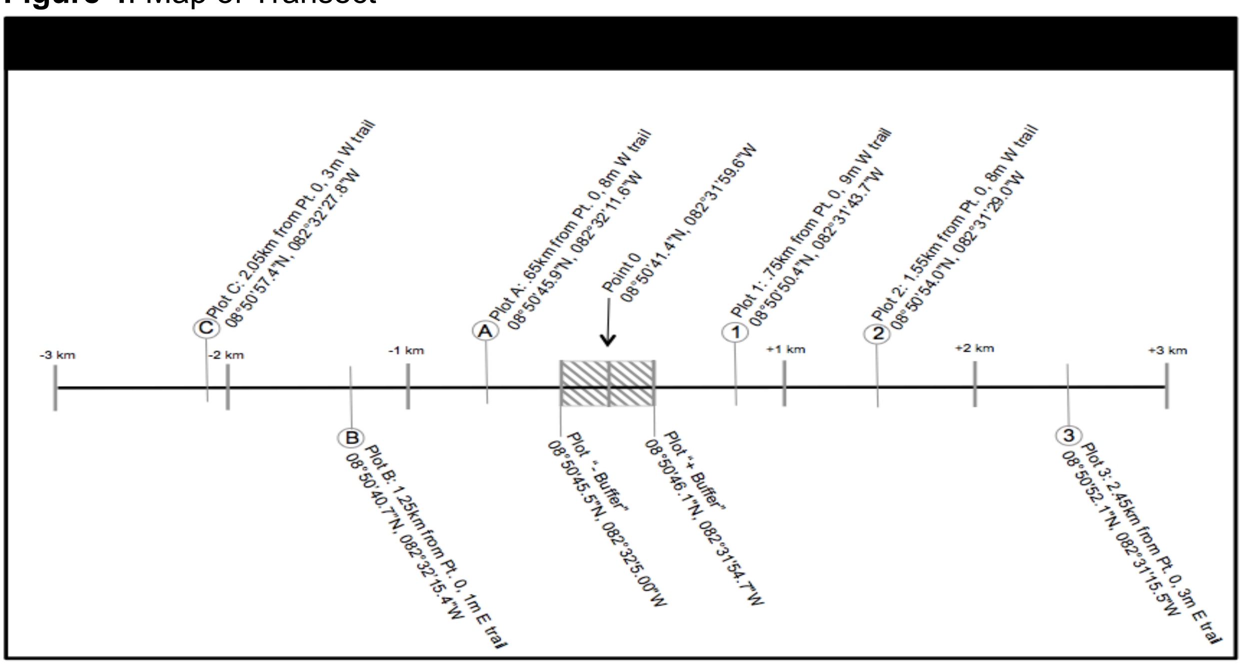
Plot Assignment	Σ dice roll	Distance from last GPS point	Distance from Plot 0	Dice roll E/W	Σ dice dist. From path
Forest interior transect					
0*	-	-	0 km		-
+ Buffer**	-	.250 km	.250 km	-	-
1	5	.500 km	.750 km	3, W	9 m
2	8	.800 km	1.55 km	3, W	8 m
3	9	.900 km	2.45 km	6, E	3 m
Outside forest transect					
0*	-	-	0 km	-	-
- Buffer**	-	.250 km	.250 km	-	-
A	4	.400 km	.650 km	1, W	8 m
B	6	.600 km	1.25 km	5, W	1 m
C	7	.800 km	2.05 km	4, E	3 m

*Plot 0 is not randomized

** Buffer plots are for spacing, not for observation

Methodology for randomization described in Alferes, 2012

Figure 4: Map of Transect



4. Rapid Vegetation Assessment

Between morning and afternoon observation hours I conducted a rapid vegetation assessment at each plot. To perform the assessment I used a form adapted from the California Native Plant Society, 2007 (see Appendix A, *Rapid Veg Assessment Form*). I completed two rapid vegetation assessments each day. The information was used to assign plot disturbance level as minimum (M), low (L), intermediate (I), or high (H). Single-file walking paths, park benches, and signs were considered low disturbance, gravel roads and fences were considered intermediate, and clearings, buildings, or cattle ranching activities were considered high. Examinations of the disturbances at the micro level were combined to determine overall disturbance level. For example, if the majority of the disturbances identified were high-level, the plot's final evaluation was high.

5. Timed Species Count and Audio Recording

I arrived at the transect at approximately 6:00 am each morning. I traveled to my first plot and recorded the basic site information. Around 6:45 am I started the audio recording and began my first TSC. The count began with a two-minute settling period, followed by 60 minutes of recording. I recorded the species' name and the time at which they were first identified. If additional individuals of that species were observed, I tallied the number next to the original sighting. At then end of the count, the 60 minutes were broken into six ten-minute ranks. Species identified within the first ten minute rank were assigned a "1", species in the second rank were assigned a "2", and so on. Around 7:45 I walked to the second plot of the day, and repeated the process around 8:15 am. In the afternoons, I conducted a TSC and recorded audio at the same two plots. I began the first around 3:45 and the second around 5:00. Although I recorded each TSC, I did not use this data to supplement my visual observations. The method for TSC was adapted from Freeman et al., 2003. (See Appendix B, *Bird Observation Form*).

6. Materials

The materials required for this study included a Garmin GPSMAP 64s, a 30-meter measuring tape, flagging tape, a Sony ICD-PX440 stereo recorder, a Sony ECM-DS70P stereo microphone, a thermometer, waterproof paper and a pencil, a clip board, and a densiometer (Forestry Suppliers Inc., Mississippi).

IX. SITE DESCRIPTIONS

1. Interior – Sendero Los Quetzales

Sendero Los Quetzles is a single-file walking-path that connects Boquete and Cerro Punta, Chiriquí. The trail is mostly dense, primary growth forest, and it is roughly six kilometers long. During this investigation I surveyed the area from the start of the trail on the Cerro Punta side inward. Plot 2 and Plot 3 consisted of primary forest. Plot 1 was secondary forest. All three interior plots had more than 75% canopy cover and dense, herbaceous ground cover. There was also a strong presence of seeding bamboo. These plots were classified as having "low" anthropogenic disturbance.

2. Plot 0 – Forest edge

Plot 0 consisted of secondary forest edge, cleared cattle fields, the ANAM station, a driveway, small parking area, and a variety of introduced flower species. Due to the forest edge, the site had a 53% canopy cover. The ground cover was mostly tall grasses and flowery shrubs. Plot 0 was continuous with the forest of the interior plots. The area was classified as having "intermediate" disturbance. Plot 0 can be seen in Figure 5.

Figure 5: Plot 0. Parque Nacional Volcán Barú, Cerro Punta Chiriquí (2015)

3. Exterior Plots

The exterior plots consisted of plots A, B, and C. Plot A was along the road leading to the start of the trail. It was surrounded by secondary regrowth forest and had a 69% canopy cover, dense, herbaceous groundcover, and seeding bamboo. Plot A was continuous with the forest of Plot 0. Plots B and C had less than 10% canopy cover, and a mostly grassy groundcover. These plots were nearly surrounded by monoculture crop fields. Plot A was classified as having "intermediate" disturbance while Plots B and C were classified as having "high" disturbance. Although this exterior land is technically part of Parque Nacional Volcán Barú, it continues to be used as farmland because it belonged to the farmers before the land gained protected status.

X. Results

Table 2: Locations of Plots and Assessment Summary

Plot	UTM Zone	Disturbance Level	Vegetation Type	UTN E	UTM N	UTM Zone
0	17P	Intermediate	Secondary Forest	0331386	0978046	17P
+ Buffer	17P	-	-	0331537	0978188	17P
- Buffer	17P	-	-	0331222	0978171	17P
1	17P	Low	Secondary Forest	0331873	0978319	17P
2	17P	Low	Primary Forest	0332323	0978428	17P
3	17P	Low	Primary Forest	0332736	0978368	17P
A	17P	Intermediate	Secondary Forest	0331022	0978183	17P
B	17P	High	Ag. Clearing	0330903	0978026	17P
C	17P	High	Ag. Clearing	0330528	0978540	17P

*Locations retrieved from Garmin GPSMAP 64s

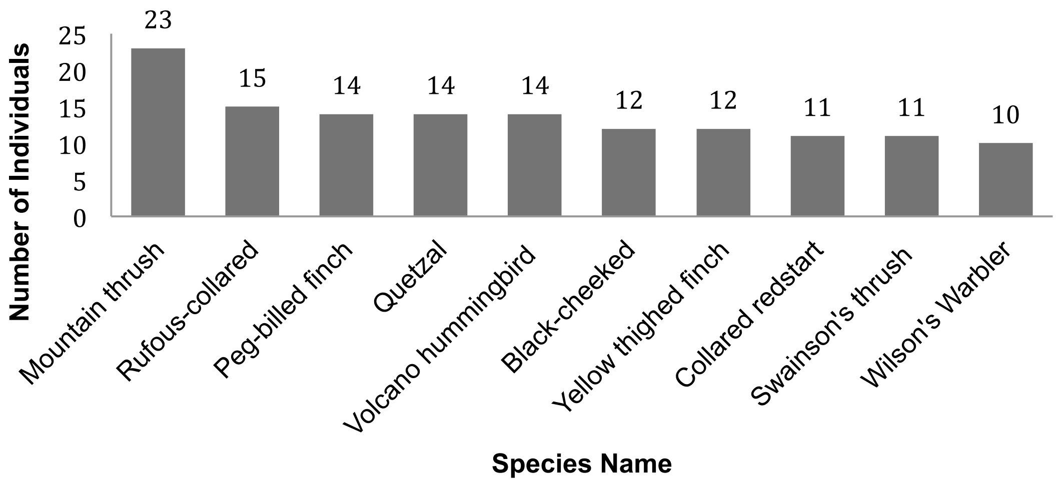
Plot assessment data including GPS location and disturbance level.

Table 3: Comparison of all plots and a total

PLOT	DISTURBANCE	# SPECIES	# INDIVIDUALS	SWBI	MOST COMMON SPECIES	#
3	low	22	36	2.791	Quetzal	7
2	low	15	34	2.601	Barred Parakeet	5
1	low	20	59	2.758	Peg-Billed Finch	10
0	int	16	52	2.558	Volcano Hummingbird	9
A	int	15	36	2.295	Collared Redstart	10
B	high	11	26	2.215	Rufous-Collared Sparrow	5
C	high	8	21	1.951	Rufous-Collared Sparrow	5
Total		**58**	**264**	**3.598**	**Mountain Thrush**	**23**

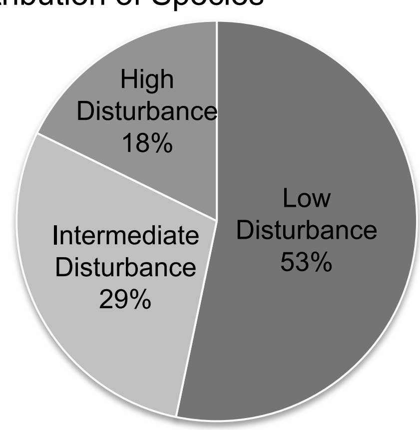
Survey data including plot, disturbance level, number of species at the plot, number of individuals at the plot, each plot's individuals SWBI, the most commonly observed species at that plot and the number of times it was observed.

Figure 6: Most Identified Species



A bar graph depicting the most commonly observed species and the number of times they were observed for all plots combined.

Figure 7: Distribution of Species



Fifty-three percent of the species were observed in areas of low disturbance

Table 4: Comparison of Disturbance and Location Categories

DISTURBANCE LEVEL	SPECIES	# INDIVIDUALS	SWBI	MOST COMMON SPECIES	#
Low	57	129	3.331	Peg-billed finch	13
Intermediate	31	88	2.841	Volcano Humminbird	11
High	19	47	2.464	Rufous-collared sparrow	10
LOCATION	**SPECIES**	**# INDIVIDUALS**	**SWBI**	**MOST COMMON SPECIES**	**#**
interior	57	129	3.331	Peg-billed finch	13
exterior	34	83	2.887	Swainson's thrush	11

Table 4 presents the SWBI values based on disturbance level and location. Table also includes the most common species found, categorically, and the number of individuals observed.

Table 5: Statistical Analysis of SBWI

TEST TYPE	P-VALUE
ANOVA - ALL GROUPS	**0.0240**
T-TEST - LOW vs HIGH	**0.0092**
T-TEST - INTERMEDIATE vs HIGH	**0.0115**
T-TEST - LOW vs INTERMEDIATE	0.1009

An ANOVA test of the three categories' SWBI values resulted in a P-value equal to 0.0240. Individual t-tests (95% CI) between low/high, low/intermediate, and intermediate/high resulted in 0.0092, 0.1009, and 0.0115, respectively.

Table 6: Jaccard and Simpson Calculations

Measurement	Value
Jaccard Coefficient	0.2941
Simpson's index of divoersity (1-D)	0.9633

Calculations of the Jaccard Coefficient and Simpson Index generated values of 0.2941 and 0.9633, respectively
.

Sources for error in this investigation include variations in weather and time of day between observations. Since I am relatively inexperienced with avian species identification, missed identifications and recordings are likely. Although not assessed in this investigation, the recordings and data from this survey can also be used to calculate abundance.

XI. DISCUSSION

The results of this study describe the current conditions of the land three kilometers inside and three kilometers outside the start of the Los Quetzales Trail in Cerro Punta. They are limited to describing the avian diversity of the high, intermediate, and low anthropogenically disturbed plots of the montane cloud forest within this area.

Due to its small scale, this investigation cannot predict that all investigations of biodiversity in anthropogenically-disturbed areas would result similarly.

1. Plot Summaries

The plot assessments determined that the areas used for crop cultivation and cattle ranching outside the trail's limits are highly disturbed. Even though there are a few secondary forest fragments scattered throughout the agricultural clearings, they are currently being deforested (observed during species inventory). These fragmented habitats are shrinking and forest continuity is being lost. Plots 0 and A formed intermediately disturbed, semi-continuous secondary forest edges and fragments. Although they were within 100 meters of large agricultural clearings, they maintained majority canopy coverage, herbaceous groundcover, as well as a variety of tree and flowering shrub species. Plots 1, 2, and 3 had low disturbance and provided a lush, diverse habitat for a variety of avian species.

2. Avian Diversity

Across all seven plots I identified 58 different avian species and 264 individual birds (Table 3). The most popular bird observed was the Mountain Thrush (23 ind.), which was found in the lower canopy, forest floor, and along the roads. The Mountain Thrush seems to be tolerable of disturbance since it was found in the low, intermediate and highly disturbed areas. Although not observed as often, the Black-faced Solitaire, was extremely vocal during observation hours, and was heard calling at each "low" and "intermediate" plot. Other common observations included the Resplendent Quetzal (14 individuals) and the endemic black-cheeked warbler (12 individuals). These observations are consistent with previous surveys of the area (Angher et al., 2006).

Figure 8: Seeding Bamboo, Parque Nacion Volcán Barú. (2015)

In both the low and intermediate plots there was a strong presence of seeding bamboo. Seeding bamboo attracts many species, particularly seed-eating birds and finches (Ridgely and Gwynne, 1989). The Peg-billed finch and Black-thighed Grosbeak were observed exclusively near the Bamboo, which can be seen in Figure 8.

The plot with the highest individual SWBI was the plot furthest into the primary forest, Plot 3. Plot 3 also reported the greatest species richness with 22 different species identified. This suggests that there are species that are limited to the primary interior forests, and that these species are unable to inhabit forest edge or disturbed matrices. The Shannon-Wiener Biodiversity Index (SWBI) for all data combined was 3.598. After separating the plots based on disturbance level, the plots with low disturbance reported the highest SWBI at 3.331. The areas of low disturbance accounted for 53% of the species observed, intermediate accounted for 29% of the species observed, and high accounted for only 18% of the species observed.

This investigation identifies an inverse relationship between disturbance and diversity. The least disturbed areas resulted in the highest SWBI and the greatest species richness, while the areas with the greatest disturbance resulted in the lowest SWBI and species richness. Other studies of avian diversity in the Chiriquí Highlands have also observed similar relationships (Jones, 2014).

The results of an ANOVA test between low, intermediate, and high disturbance groups allow us to reject the null hypothesis and conclude that there is a statistical difference between each group's biodiversity (P-value 0.0240). To further interpret the data, I compared each group using a T-test. When comparing the SWBI's of the low and intermediate plots, we observe no statistically significant difference between the diversities (P-value 0.1009). Therefore, we can conclude that intermediately-disturbed, secondary plots support regional avian diversity. When comparing the SWBI's of the low and intermediate disturbance plots to the high disturbance plot, we observe P-values equal to 0.0092 and 0.0115, respectively. We conclude that there is a significant difference between the diversity of the low and intermediate plots and the diversity of the highly disturbed plots. This shows that the highly disturbed areas that have been cleared for agriculture or cattle ranching are unable to support the region's natural avian diversity. P-values were calculated with 95% confidence intervals.

The Jaccard Coefficient calculates similarity between two populations. The calculated value, 0.2941, shows that the exterior and interior populations (excluding Plot 0) do not share many of the same species. This suggests that many of the species found in the undisturbed forest plots are unable to flourish in disturbed areas. As disruption spreads, habitable land shrinks, and species richness decreases. The Simpson's Diversity Index is a measure of diversity that takes into account both species richness and evenness. The Simpson's 1-D represents the probability that two individuals randomly selected from a sample will belong to different species. The calculated Simpson's Diversity Index (1-D) for this dataset was 0.9633. This indicates that there is nearly a 100% probability that two randomly selected individuals from the exterior and interior populations would be different species. This reinforces the conclusions drawn from the T-tests and from the Jaccard Coefficient calculation. The types of species found in the interior and exterior plots are very different.

3. Protection and Preservation

Similar studies agree that large agricultural clearings and cattle ranching cannot support avian diversity (Van Bael et al., 2007: Jones, 2014). The cleared fields become uninhabitable, and the surrounding forest becomes isolated. The observed decrease in species richness can be explained by the Island Biogeography Theory. This study, among others (Mendenhall, 2014), suggests that protection policies should focus on preventing the development of such terrestrial islands.

We observed in Plot 0 and in Plot A, that continuous secondary forests are capable of supporting avian diversity, even when there are large clearings nearby. This suggests that continuity should also be a priority of conservation efforts. Furthermore, the introduced flowering shrubs and fruit bearing trees found at Plot 0 and Plot A supported a variety of species not found at any other study sites—such as the Slaty Flowerpiercer. Planting trees and shrubs that are know to support high species diversity near and between agricultural sites could help minimize the effects of complete deforestation.

Other methods for protection and preservation of avian species in the Chiriquí Highlands could include the implementation of agroforestry and plantation forest projects. These methods would result in similar landscapes as the intermediately disturbed areas that I surveyed and would allow farmers to continue to profit from the land without eliminating entire habitats (Van Bael et al., 2007).

XIII. CONCLUSION

This research adds to previous studies of avian diversity in Cerro Punta and Parque Nacional Volcán Barú (Jones, 2014). It is one of the few investigations that specifically describe the effects of anthropogenic disturbance on avian diversity in the Chiriquí Highlands. After the assessment of seven different plots, I was able to assign disturbance levels as low, intermediate or high based on the number, type, and severity of the disturbances present at each site. After collecting species data, I calculated the Shannon-Wiener Biodiversity Indices for each disturbance category, and compared the values using an ANOVA analysis and T-test. I found that there is no statistical difference in species diversity between low and intermediate disturbance plots. However, there is a statistical difference between both the low and intermediate categories and the highly disturbed category. The results of the Simpson's index and Jaccard coefficient revealed differences between the interior forest species and the exterior forest species. This research concludes that the highly disturbed areas outside the Los Quetzales Trail do not support the regional avian diversity.

Despite this study's small scale and sources of error, this information should be considered during the development of the immediate surrounding areas and the PILA buffer zones. Future research should focus on increasing sample size for each disturbance level. Increasing sample size may reinforce the conclusions drawn from this investigation. Other research should include the viability of agroforestry and plantation forests and biodiversity maintenance and preservation.

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Appendix A

Final vegetation type name:	**Final assessment of disturbance:**

I. LOCATION/ENVIRONMENTAL DESCRIPTION		
Site:	**Point #:**	**Date:**

Diameter of inspection (m):	**Name of surveyor:**
GPS waypoint #:	**GPS name:**

Zone #:	**UTME:**	**UTMN:**
Elevation (m):	**Geology code:**	**Soil texture code:**
Topography:	**Macro:** top upper mid lower bottom **Micro:** concave flat convex undulating	Upland Wetland/Riparian
Slope direction:	**Slope steepness:**	

II. DISTURBANCE		
Type/Code:	**Level: (M/L/I/H)**	**Notes:**
1.		
2.		
3.		
4.		
5.		
6.		
7.		

III. HABITAT AND VEGETATION DESCRIPTION	
Avg. Tree DBH:	**% Canopy Cover:**
Groundcover:	
Forest type:	

IV. NOTES	
Start time:	**Stop time:**

Appendix B

Site:	**Point #:**	**Date:**	**Visit #:**
Name of surveyor:	**GPS waypoint #:**	**GPS name:**	
Zone #:	**UTME:**	**UTMN:**	
Elevation (m):	**Temp °C:**	**Beaufort scale:**	**Conditions:**
Start time:	**Stop time:**	**Shift: AM / `PM**	**Diameter of survey (m):**
Disturbance level:	**Final vegetation type name:**		

Time 1st sight.	**Rank**	**Species:**	**# of ind.**	**Band/flyover:**	**Notes:**